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PB-258 760-T

Gas Resistance and Certain Characteristics of Absorption of S3502 by Lawn Grasses

Environmental Protection Agency, Research Triangle Park, N C

1971

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA TR75-20	2.	PB 258 760-T

4. Title and Subtitle
Gas resistance and certain characteristics of absorption of $S^{35}O_2$ by lawn grasses

5. Report Date 1971

6.

7. Author(s)
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8. Performing Organization Rept. No.

9. Performing Organization Name and Address
TRANSLATED FROM RUSSIAN BY EPA

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Translation Service
Office of Administration - Library
Research Triangle Park, NC
27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes
Perm Order of the Red Banner of Labor A.M. Gor'kiy State University, 277(5) 1971, pp. 137-142

16. Abstracts

17. Key Words and Document Analysis. 17a. Descriptors
EPAISD

17b. Identifiers/Open-Ended Terms
AIR POLLUTION - EFFECTS ON PLANTS

17c. COSATI Field/Group 13B 68A

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

PRICES SUBJECT TO CHANGE

18. Availability Statement
THIS TRANSLATION WAS MADE FROM A NON-COPYRIGHTED TEXT

19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 14
20. Security Class (This Page UNCLASSIFIED	22. Price $3.50

300033

EPA-TR 20-75

GAS RESISTANCE AND CERTAIN CHARACTERISTICS OF ABSORPTION OF $S^{35}O_2$ BY LAWN GRASSES

[Gazoustoychivost' i nekotoryye osobennosti pogloshcheniya $S^{35}O_2$ gazonnymi travami]

by

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Published in Uchenyye zapiski Permskogo ordena trydovogo krasnogo znamenii gosudarstvennogo universiteta im. A. M. Gor'kogo
[Proceedings, Perm Order of the Red Banner of Labor A. M. Gor'kiy State University, 277(5) 1971, pp. 137-142]

Practically no one was occupied with study of the resistance of lawn grasses to sulfur dioxide in the USSR after Krasinskiy (1950) and Ye. I. Knyazeva (1950). In the industrial enterprises of the Urals, in connection with the lower resistance of woody plants, lawns make up a considerable proportion of the territory planted with greenery.

In the majority of cases, gas resistance of plants is determined by susceptibility to damage of leaves by the visual estimation method (Krasinskiy, 1950) or by survival of plants under new, unfavorable conditions (Bulgakov, 1958). These methods are comparatively rough and frequently uncertain: the first, because of subjectivity and low accuracy and the second, because of the effect of a whole series of other factors (soil toxicity, change in soil microflora composition, their water conditions, etc.). The accuracy of the visual estimation method of determination of

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Translated for NERC Library, EPA, by LEO KANNER ASSOCIATES, P. O. Box 5187, Redwood City, California 94063, (415) 365-3046, November 1974.

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the percent damage of leaf surfaces (±10%) depends on the leaf configuration, its degree of dissection and the configurations of the spots, the burns on the leaves. In species of plants having more regular geometric leaf shapes (Tartar honeysuckle, common bird cherry), the susceptibility to damage can be determined more accurately by the visual estimation method. It is very important to develop new, more precise methods of evaluation of plant resistance, for solution of many theoretical problems of gas resistance of plants. Determination of the percent damage of the leaf surface, by means of the gravimetric and planimetric method is a laborious process. In this connection, we have developed and are using a metric method of determination of plant susceptibility to damage, but it is usable only for certain groups of plants. Monocotyledonous and coniferous plants are the most convenient objects of study, from this point of view. The elongated leaf shape of lawn grasses and the needles of gymnosperm species permit the subjective visual estimation method to be rejected and make it possible to determine the susceptibility to damage, as the ratio of the length of the damaged part of the leaf to the total length in percent. Consequently, the percent of damaged length of the leaf, provisionally taking it as damage to the plant by gas, can be determined by this method. The susceptibility to damage of lawn grasses can easily be determined, by means of a ruler, since the burns on them begin at the leaf tip, as a rule.

On the other hand, the phases of growth and development have been studied in greater detail in grasses than in dicotyledons and woody plants. This makes it possible to study the gas resistance of plants in development, in connection with the patterns of growth and development. Lawn grasses are a convenient object, because they can be studied practically the year

around: in summer under field conditions and, in the winter, in laboratories, using the greenhouse method.

In previous studies (Nikolayevskiy, 1964), it was shown that differences in gas resistance of woody plants are connected with the rate and amount of absorption of an acid gas by the plants. Nonresistant species (common birch, Manchurian walnut) absorb lethal concentrations of sulfur dioxide more quickly and, therefore, they are damaged more severely.

We have attempted to study the dependence of susceptibility to damage of lawn grasses on accumulation of $S^{35}O_2$ and the effect of the contaminated soils of a chemical plant on plant resistance.

Experimental Method

Lawn glass plants were grown on peat (1.5 cm thick) in Petri dishes, in the Botanical Garden Conservatory, in January 1968 and, when 22 days old, in leaf phases 1-2, they were fumigated with sulfur dioxide for a period of one hour. The SO_2 concentration was 0.3% by volume, and the specific activity of the gas was 0.5 μc per liter. In the test versions, the lawn plants were watered a day before gassing: the control with water, test version I with a water extract of soil from the first section of the chemical plant (400 g of soil plus 600 ml of water), version II with a water extract of the soil from section 3 of the chemical plant.

In the second test: 11 species of lawn grass were grown on peat (control) and in the soils from sections 1 and 3 of the chemical plant. The plant seeds from the soil from section I did not germinate, and 6 of 11 species germinated in the soil from section 3. At 40 days old, in leaf phases 1 and 2, they also were gassed with sulfur dioxide for a period of one hour. The SO_2 concentration and specific activity were the same.

The activities of fresh and dry leaves were determined by a SBT-7 end-window counter, in a B-2 unit. The damage and activity were counted a day after repeating the fumigation 10 times. In addition, for each species, the activity was determined separately in the damaged and undamaged parts of the leaves four times. The results of the study were processed by the biometry method (Leont'yev, 1961). The studies using S^{35} were performed in the Radiochemistry Laboratory, ENI University.

Results of Study

The results of treatment of plants grown on peat and watered before the test with a water extract of oils from a chemical plant are presented in Table 1. It is clear from them that the following proved to be most resistant to SO_2 among the control plants: orchard grass and meadow fescue. Sulfur dioxide caused heavy damage to timothy grass, Hungarian brome, white bent and red clover.

The hypothesis of the direct dependence of susceptibility to damage of different types of plants on amount of sulfur dioxide absorbed turned out to be true for only 4 species (red clover, common foxtail, Hungarian brome and tall rye grass) and, at the same time, a dependence of susceptibility to damage of the plants on accumulation of $S^{35}O_2$ is nearly always found clearly in the populations of each species. It might be assumed that the differences in gas resistance of individual species of plants are connected with the physiological and biochemical characteristics of the plants. In the populations of each species, the susceptibility to damage of the leaves is determined by their anatomical and morphological characteristics and the amount of the toxic gas absorbed.

TABLE 1

SUSCEPTIBILITY TO DAMAGE AND CERTAIN CHARACTERISTICS OF ABSORPTION OF $S^{35}O_2$ BY LAWN GRASSES.

a Виды	b Контрольные растения					c Опыт, I вариант				
	d Повреждаемость в % длины листа	e Средняя активность 1 растения имп/мин.	f Активность 1 мм поврежд. части листа в имп/мин	g Активность 1 мм неповрежд. части	h Активность 1 г сухого вещества в имп/мин.	d Повреждаемость в % длины листа	e Средняя активность 1 растения имп/мин.	f Активность 1 мм поврежд. части листа имп/мин.	g Активность 1 мм поврежд. части листа имп/мин.	h Активность 1 г сухого вещества в имп/мин.
i Ежа сборная . . .	4,4	34,4	1,07	0,21	22 940	31,5	50,2	0,98	0,25	29 970
j Овсяница луговая	13,6	54,4	3,36	0,57	41 975	21,4	59,1	1,20	0,10	31 670
k Клевер луговой	63,5	52,1	—	—	24 000	65,0	51,5	—	—	22 600
l Лисохвост луговой	37,4	37,5	0,61	0,29	25 000	54,5	47,3	1,25	0,36	29 080
m Пырей ползучий	26,6	53,5	1,47	0,56	29 400	37,9	54,7	1,44	0,21	28 470
n Райграс высокий	25,7	32,9	0,80	0,15	28 220	45,5	35,4	2,05	0,16	20 400
o Костер безостый	45,6	128,4	1,44	0,27	53 360	56,0	111,3	1,62	0,16	44 720
p Полевица белая	52,5	21,1	0,19	0,19	23 550	37,6	21,6	0,78	0,07	26 200
q Тимофеевка луговая	49,9	29,4	0,81	0,24	26 960	66,1	35,4	1,27	0,05	33 570

Key:
- a species
- b control plants
- c test version I
- d damage in % of leaf length
- e average activity of one plant, count/min
- f activity of 1 mm of damaged section of leaf, in count/min
- g activity of 1 mm of undamaged part
- h activity of 1 g of dry matter, in count/min
- i orchard grass
- j meadow fescue
- k red clover
- l common foxtail
- m couch
- n tall rye grass
- o Hungarian brome
- p white bent
- q timothy grass

[Translator's Note: Commas in tabulated numerals are equivalent to decimal points.]

To determine the threshold lethal SO_2 concentrations for plants, the S^{35} activity was accounted for in damaged and undamaged parts of the leaf. The studies have shown (Table 1) that the amount of S^{35} in the damaged part of the leaf is 3-10 times more than in the undamaged part. A similar picture was observed in test versions I and II. It can be assumed that the nature of damage of the leaf in lawn grasses involves migration of sulfur through the vessels with the water flow. This facilitates increasing the sulfur concentration at the leaf tips and, as a consequence, the appearance of necroses.

Individual species of plants can create various types of organic substances in the process of assimilation, during their lifetime and even in a short time. Therefore, to reveal the differences between species, a calculation of $S^{35}O_2$ absorption by one plant and by 1 gram of dry substance was carried out (Table 1). While a single plant of each species absorbed differing amounts of SO_2, in calculation per gram of dry substance, with the exception of two species (Hungarian brome, meadow fescue), the absorption of gas was similar. Consequently, the gas resistance of different species of plants is determined, to a considerable extent, by their physiological and biochemical characteristics. On the other hand, accumulation of lethal doses of SO_2 in resistant species was 3-5 times higher than in nonresistant ones.

Meadow fescue and Hungarian brome considerably exceed the remaining species in SO_2 accumulation. At the same time, the damage to the first species was 13.6% and, to the second, 45.6%. The ability of some gas resistant species (meadow fescue) to absorb a considerable amount of gas, without particular harm to them, has a great sanitary-hygienic value. The use of such plants in planting greenery can give a more significant effect, in the sense of purifying polluted air. For a definitive evaluation of the hygienic role of individual species, however, the remote aftereffects of the gas on the plant must be studied.

Calculations of gas absorption by 1 g of dry substance showed that 5-10 times more S^{35} is accumulated in the damaged parts of leaves of resistant plants than in the undamaged parts of the leaves. In plants not resistant to sulfur dioxide, the S^{35} activity in the damaged part is equal to or only 1.5 times that in the undamaged part. Consequently, lethal

concentrations of the gas in resistant species of lawn grass are considerably higher than in nonresistant ones.

The differences in susceptibility to damage of lawn grasses is statisically significant only for species of different resistance groups, which contrast sharply: between resistant ones (meadow fescue, orchard grass) and nonresistant (Hungarian brome, white bent). Differences in susceptibility to damage of plants of closer groups (resistant and moderately resistant ones) are not significant or are on the borderline of significance. This can be explained by the comparatively high biological variation in gas resistance of plants (V is from 21 to 100%).

With a single watering of the plants, with a water extract from the factory soils on the second day, a drop in turgor was noted in some species.

In test version I, an increase in damage was observed in 7 species (Table 2) and a decrease in 2 species. In version II, the opposite effect in change in susceptibility to damage of the plants was uniformly distributed. A reduction in gas resistance in both versions was revealed in 5 species (red clover, common foxtail, couch, timothy, tall rye grass) and an increase in gas resistance in 2 species (meadow fescue, white bent).

The difference in the effect of the water extract of factory soils on resistance of plants to SO_2 apparently involves the presence of various toxic compounds in the soils (version I, fluorine and a high superphosphate content; version II, iron, sulfur and nitrogen oxides).

The increase or decrease in damage of plant species (Table 1) in versions I and II coincided with the corresponding changes in $S^{35}O_2$ accumulation, with rare exceptions. This again indicates that, within the population of a species, plant damage depends to a greater extent on accumulation

of the toxic gas and all those anatomical, morphological and other characteristics of the plant, which regulate the rate of absorption of the gas.

To judge by the average activity of 1 mm of the damaged part of the leaf, lethal concentrations of SO_2, like the level of accumulation of gas in gas resistant plants, differ. Gas resistant species can accumulate in their tissues and tolerate higher SO_2 concentrations. It might be proposed that resistant species are better and more completely capable of absorbing SO_2 in their tissues.

We attempted to trace the relation of plant susceptibility to damage by sulfur dioxide and growth rate. Statistical calculations demonstrated that, in the lawn grasses which we studied, there is a close to significant inverse connection between leaf dimensions and damage. Consequently, as N. P. Krasinskiy considered (1950), rapidly growing species have increased gas resistance. The increased resistance of the latter is connected not only with the greater rate of renewal of leaf mass, but with the specific characteristics of the physiological and biochemical processes and metabolism of the plants.

In the second test, in the case of growing plants directly in the factory soil, it turned out that none of the species in the soil of section 1 germinated and that sparse sprouts of 6 species appeared in the soils of section 3 (Table 2). Red clover, orchard grass and white bent did not germinate. The plants in the second test differed sharply from controls, not only by less germination, but in size and color. The plants in the factory soil grew more succulent (shortened and thickened), and they frequently were darker green. Appearance of necroses on the leaf tips, owing to the toxicity of the soil, was observed in some species. The toxic

compounds in the factory soil caused, not only slowing of growth, but slowing of development.

TABLE 2

SUSCEPTIBILITY TO DAMAGE AND CERTAIN FEATURES OF ABSORPTION OF $S^{35}O_2$ BY LAWN GRASSES

a Виды	b Контрольные растения			c Опытные растения		
	d Повреждаемость в % длины листа	e Средняя активность 1 растения в *имп/мин*	f Активность 1 г сухого вещества в *имп/мин*	d Повреждаемость в % длины листа	e Средняя активность в *имп/мин*	f Активность 1 г сухого вещества в *имп/мин*
1. Овсяница луговая . . .	5,9	20,2	10 560	0	4,5	2990
2. Лисохвост луговой . . .	71,5	58,8	34 070	0	2,4	1980
3. Пырей ползучий	31,2	37,7	25 370	0	2,6	2160
4. Костер безостый	24,7	58,6	31 050	16,9	6,8	3640
5. Тимофеевка луговая . .	49,4	14,0	23 550	2,9	4,7	3400
6. Костер безостый	3,1	48,2	25 910	0	2,8	1190

Key:
- a species
- b control plants
- c test plants
- d damage in % of leaf length
- e average activity of 1 plant, in count/min
- f activity of 1 g of dry substance, in count/min
- 1 meadow fescue
- 2 common foxtail
- 3 couch
- 4 Hungarian brome
- 5 timothy
- 6 Hungarian brome

A comparison of the extent of the effect of the factory soils on growth and development of different lawn grasses with their gas resistance showed that there is no direct connection between these characteristics. Consequently, a reliable judgment on the gas resistance of a plant cannot be made, from survival of plants under new, unfavorable conditions of existence. Gas resistance cannot be identified with plant survival. In the first test (Table 1), a comparatively high gas resistance of orchard

grass was found, but it did not even germinate in factory soil.

Control lawn grass plants in the second test (Table 2) gave comparatively close damage indices to those of the test plants, with the exception of common foxtail. At the same time, there are differences in the nature of $S^{35}O_2$ absorption. They are connected with differences in age: because of poor germination and growth of the test plants, they were gassed at 40 days of age, when the control plants differed considerably from the controls in the first test. The test plants (version II) turned out to be more gas resistant (Table 2). The decrease in plant damage by sulfur dioxide distinctly coincides with less gas absorption. The activity of dry substance of the test plants turned out to be lower than that of the controls, by 3-20 times. Retardation of plant growth in factory soil, their increased succulence and cutinization caused an increase in gas resistance of the plants.

Conclusions

1. Lawn grasses are the most convenient objects for study of patterns of gas resistance, since they permit the subjective visual estimation method of damage evaluation to be avoided. We developed a new method of determination of susceptibility to damage to lawn grass plants.

2. It can be proposed that differences in gas resistance of individual species are determined by the physiological and biochemical characteristics of the plants and that, in the populations of each species, by the anatomical and morphological characteristics of the leaf structure and amount of acid gas absorbed.

3. It has been determined that the S^{35} activity of all species of plants is 3-25 times higher in the dead leaf tissues than in the living.

It can be proposed that S^{35} transport through the vessels with the water flow to the leaf tips is accomplished to a greater extent in monocotyledenous plants than in dicotyledenous ones.

4. Toxic compounds accumulated by the soil, depending on concentration and chemical nature, can cause death of seeds or decrease in germination, impairment of growth and development of the plants and change in resistance to SO_2 (an increase in gas resistance was observed, for the most part).

5. Lethal concentrations of SO_2 in plants of resistant species are higher than in nonresistant ones. It can be proposed that the former are capable of better and more completely absorbing SO_2 in their tissues.

6. Plants with larger leaf surface dimensions proved to be more resistant to SO_2. This dependence can be connected with characteristics of the physiological and biochemical processes in species with different growth rates.

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